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ESTIMATES OF CONVERSION FROM 200 TO 400 BEV

F. T. Cole
T. L. Collins

The 200 BeV accelerator designed by the National Accelerator Laboratory has provision for future conversion to a higher energy. The main-ring magnets have been designed to give almost 500 BeV when powered to their maximum possible field. In addition, adequate magnet cabling and water piping for the higher power operation have been provided, so that a conversion program can proceed without extensive work in the magnet enclosure and thus without a major shutdown of the facility. Other components of the accelerator are designed for 200 BeV only and this report discusses the nature and approximate cost of their conversion for higher energy operation.

The nature of the conversion depends strongly on the choice of the new cycle time for the higher energy. For example, the repetition frequency could be lowered enough that the <u>average</u> power into the magnets was not increased at the higher energy. This slow cycle mode of operation would require only modest improvement to a few components, such as the rectifiers in the magnet power supply, but it would give a considerably lower average current and duty cycle. We hope to use the slow cycle mode for occasional operation to extend the range of some important experiment, say from 200 to 300 BeV, but it is not a true conversion.

For routine operation at higher energy, we should have the same ~~average current and duty cycle as before conversion.~~ ~~We have~~ chosen ~~a~~ cycle that will do this at 400 BeV. After conversion the slow cycle mode can be used for occasional operation at 500 BeV should this prove practical. Note also that after conversion, 200 BeV operation can have an increased current and a better duty cycle.

The cycles are shown in Fig. 1. The normal 200 BeV cycle has a 1-second flat-top and a 4-second total period. The 400 BeV cycle has a 2-second flat-top and an 8-second period. Both cycles therefore have a 25 percent duty cycle. The 400 BeV cycle has twice the filling time of the 200 BeV cycle, allowing twice the charge per cycle, so that the average current is the same in both cases. The booster must inject two turns into the main ring but is not otherwise affected by the conversion to higher energy.

The accelerator components that require modification in the conversion program are: magnet power supply, cooling system, injection, radio-frequency system, extraction, external-beam handling and controls. In addition some provision is necessary for increased target shielding and experiment space. The major effort and cost are the conversion of the magnet power supply.

The magnet power must be increased by a factor of four, from 17 to 68 megawatts. Some modification to the existing supplies will be required but most of the power increase will come from the installation of additional units, including additional filtering and power-factor correction. These units are outdoor equipment so that installation requires pads, conduits, etc., and only minor building modifications. The increased load on the substation will be handled by the installation of forced-oil, forced-air cooling on existing units. It is now believed that this increased load can be connected directly to the power line. The costs would not be substantially different if motor-generator sets were used.

The greater magnet power will increase the magnet heating. During the conversion the magnet cooling-water pressure will be doubled by additional pumps to increase the water flow. Nevertheless the magnet temperature rise will be more than doubled, from 6°C to 16°C. The magnets are excessively cooled at 200 BeV operation in anticipation of the conversion, so no trouble is expected. The accelerator cooling towers must be greatly increased to handle the power and some enlargement of the water treatment and handling system may be necessary.

The radio-frequency accelerating system must also be enlarged considerably. The present design has a beam loading of about 1/3, that is, one-third of the power is transferred to the beam of protons with the rest being dissipated in the rf system. For 400 BeV operation, we will load twice as many protons into the main ring, so that rf power capability must be increased by 50 percent to maintain this ratio. Exactly how this is done, by increasing the number of units or their individual power or both, is best determined after experience with the rf system.

Both the injection and extraction systems will require extensive modification. The injection system will be changed to a two-turn system and the slow-extraction system must work at twice the energy for twice as long. Although both conversions present some technical difficulty, neither is very costly. The design of these new systems will be greatly aided by a period of operation at 200 BeV.

The magnets in the external beam run are copies of the main-ring magnets and can therefore be used without modification. The power supplies for these magnets must be increased.

The general control system of the accelerator must be enlarged to provide monitoring and control of the new equipment and to provide new timing circuits.

One must include some provision for using the extracted 400 BeV beam. The estimate includes the cost of improving one target station to a 400 BeV standard by increasing the shielding and extending the length of the secondary beam buildings and services. The target shielding, in theory, must be twice as long but not any thicker. This is a very expensive part of the conversion and one would not like to do it before actual experience with 200 BeV shielding problems. We can, however, predict with confidence that the accelerator itself will not need any extra shielding.

Table I is a cost summary for the conversion. The costs are listed in two columns, one for accelerator components and one for conventional construction. EDIA is estimated at 25 percent for the first and 17-1/2 percent for the second, except for shielding which is estimate at 5 percent. An overall contingency of 25 percent is added on both accelerator components ~~and conventional construction. This larger contingency on conventional~~ items is judged to be appropriate in view of the relatively early stage of the conversion design. No real estimate of escalation is possible. These figures represent present-day (1967) costs. If the conversion project were started in six years and completed in seven and one-half years, which is a good schedule, the costs would obviously increase over these figures, perhaps by as much as one-third.

TABLE I

Conversion Costs in Millions of 1967 Dollars

Component	Accelerator	Conventional	
Magnet Power	7.0	2.2	
A.C. Service		0.4	
Cooling		3.0	
Water System		0.5	
Radio Frequency	1.4		
Injection and Extraction	0.5		
Beam Handling	1.0		
Controls	0.3		
Targeting			
Shielding		2.0	
Building Extension		2.0	
	10.2	10.1	
EDIA	2.6	1.5	
	12.8	11.6	24.4
Contingency			6.1
Total without Escalation			30.5